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Nutritional Quality of Soybean Seeds Relative to Canopy Portion

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Abstract

Soybean [*Glycine max* (L.) Merr.] seed quality (nutritional composition) is affected by genetic \times environment \times management ($G \times E \times M$) interactions. Even at the plant level, where differences might not be largely apparent, seed quality is known to change. This study aims to 1) compare seed yield and nutritional quality within the vertical profile of soybean plant canopy, and 2) explore potential interactions for different genotypes. A field experiment was conducted in Manhattan, KS, during the 2018 growing season. Treatments were composed by six genotypes and evaluated at four canopy portions: upper, middle, and lower sections of the main stem and branches. The study was set in a complete randomized block design with three replications. Seed yield and seed size were determined at physiological maturity, as well as seed quality (e.g., protein and oil concentrations). For seed yield, the contribution of the branches was directly affected by the genotype, while the other portions presented a similar yield across genotypes. Seed size was greater in the upper and middle portions of the plant canopy, and seed size of the branches was always comparable to the average of the main stem sections. Overall, oil concentration was lower in branches and did not differ along the sections of the main stem. On the other hand, the protein concentration was greater in the upper portion of the plant. Further research should explore seed quality responsiveness to the timing of pod-setting and seed-filling within the soybean canopy.

Keywords

Glycine max, genotype, protein, oil

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Nutritional Quality of Soybean Seeds Relative to Canopy Portion

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Summary

Soybean [*Glycine max* (L.) Merr.] seed quality (nutritional composition) is affected by genetic \times environment \times management ($G \times E \times M$) interactions. Even at the plant level, where differences might not be largely apparent, seed quality is known to change. This study aims to 1) compare seed yield and nutritional quality within the vertical profile of soybean plant canopy, and 2) explore potential interactions for different genotypes. A field experiment was conducted in Manhattan, KS, during the 2018 growing season. Treatments were composed by six genotypes and evaluated at four canopy portions: upper, middle, and lower sections of the main stem and branches. The study was set in a complete randomized block design with three replications. Seed yield and seed size were determined at physiological maturity, as well as seed quality (e.g., protein and oil concentrations). For seed yield, the contribution of the branches was directly affected by the genotype, while the other portions presented a similar yield across genotypes. Seed size was greater in the upper and middle portions of the plant canopy, and seed size of the branches was always comparable to the average of the main stem sections. Overall, oil concentration was lower in branches and did not differ along the sections of the main stem. On the other hand, the protein concentration was greater in the upper portion of the plant. Further research should explore seed quality responsiveness to the timing of pod-setting and seed-filling within the soybean canopy.

Introduction

Consumers, industry, and farmers are facing concerns about the nutritional quality of soybean seeds due to soybean's worldwide importance as a food crop. Consequently, plant breeders have been trying to enhance the composition of soybean meal while maintaining a high yield potential. Crop physiology studies might help to maximize genetic improvements and provide a better understanding of the plant allocation of nutritional components to the seeds. This study aims to 1) compare seed yield and nutritional quality within the vertical profile of soybean plant canopy, and 2) explore potential interactions for different genotypes.

Procedures

Site Characteristics

The experimental field was located at the Ashland Bottoms Research Farm, Ashland Bottoms, KS (39.14° North, 96.64° West). The area was under rainfed conditions during the 2018 growing season. Soil parameters were collected for initial character-

ization. The area presented a pH in water of 7.6; a texture of 18% clay, 54% silt, and 28% sand; 90 ppm of phosphorus (Mehlich); and 2.1% of soil organic matter (SOM), considering a soil layer of 6-inch depth.

Soybean was sown on April 27 and harvested on October 10, 2018. The harvesting date was defined based on the overall field onset of the R8 stage (full maturity) (Fehr et al., 1971). The average plant density was 83,000 plants per acre with a row spacing of 30 inches. Additional nutrients were not applied, and the crop was kept free of weeds, diseases, and insects.

Weather data were obtained from the closest land station (Ashland Bottoms) (Kansas Mesonet, 2017). The average temperature during the growing season was 75°F, with maximum and minimum daily averages of 85°F and 63°F, respectively. Cumulative precipitation during the growing season was 24.9 inches. The average relative humidity was 70%.

Experimental Design

The experiment was set in a complete randomized block design with three replications. Treatments were composed of six soybean genotypes (Table 1) and each plot had six rows (15-foot width) with 50-ft length (Figure 1a). At harvest, plant samples from each plot were partitioned into upper, middle, and lower sections of the main stem, apart from the branches (collected all together) (Figure 1c). Overall, portions of the main stem had five nodes each.

Measurements

The measurements were divided into groups by yield and nutritional quality. The first group accounts for seed yield (bu/a) at 13% moisture, and seed size (lb/1000 seeds). The second group accounts for protein and oil concentrations (%) on a wet basis (13% moisture). Seeds were collected by manually harvesting three rows, excluding the borders, each with 5-ft length (15 linear feet) (Figure 1b). Quality data were obtained by the near infrared (NIR) method (Pazdernik et al., 1997).

Statistical Analysis

Statistical analyses were done in the following steps: 1) parameters of the entire plant were used to characterize the genotypes (single fixed factor); and 2) parameters considering canopy portion \times genotype were tested as fixed factors. In both cases, linear mixed models were adjusted, accounting for block as a random component. The analysis of variance (ANOVA) assumptions were tested, and the Tukey test was adopted for means comparison when significant responses were found ($P < 0.05$). Analyses and graphs were processed with the R software (R Core Team, 2018).

Results

Before looking at the distribution of seed yield within the canopy portions and the behavior of nutritional quality parameters, a comparison between genotypes was conducted. Table 2 presents the means and their comparisons for seed yield, seed size, protein and oil concentrations. All variables are accounting for the entire canopy and were statistically affected by the genotype.

When considering the canopy portion, interactions were found for seed yield (Figure 2), seed size (Figure 3), and oil (Figure 4), while protein was only affected by single effects (Figure 5). Differential seed yield and nutritional quality throughout the plant canopy might be related to nutrient remobilization, branching, and growth rate, as well as the pod-setting and seed-filling variability. According to Huber et al. (2016), these differences in seed composition throughout the canopy can be studied to improve soybean quality by harvesting specific portions separately.

Seed yield from the three sections of the main stem was similar across genotypes, but the contribution from the branches was inconsistent. This could be explained by the uniform division of the main stem sections, while branching is directly related to the genotype and plant density.

Overall, seed size was greater in the middle and upper portions, while seed size in branches was comparable to the average of the entire main stem. The limited number of main stem sections probably hid a smaller seed size in upper nodes of the main stem.

The oil concentration pattern throughout the canopy was affected by the evaluated genotype. The tested genotypes might have variability coming from the plant architecture and duration of seed filling, even within the plant canopy. This variability could expose the seeds to diverse environmental conditions, which will have strong impacts on the oil concentration.

For protein concentration, a diminishing pattern was documented from the upper to the lower section of the plant, as reported by Collins and Cartter (1956). However, there are few recent publications exploring environmental and physiological factors to explain this trend. In addition, the allocation of amino acids should also be investigated in forthcoming studies.

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Table 1. Soybean genotype tested for yield and nutritional quality distribution within the plant canopy portions. All provided by DuPont Pioneer (Corteva Agriscience, Johnston, IA)

Genotype	Variety	Year of release	Maturity group
A	P39T67R	2014	3.9
B	P35T58R	2013	3.5
C	94Y23	2013	4.2
D	93M90	2003	3.9
E	P31T11R	2016	3.1
F	P34T43R2	2014	3.4

Table 2. Seed yield, seed size, and nutritional quality parameters for the entire plant

Genotype	Variety	Seed yield	Seed size	Protein	Oil
		----- bu/a -----	- lb/1000 seeds -	----- % (w/w)† -----	
A	P39T67R	82.7 a*	0.338 b	31.46 ab	20.03 bc
B	P35T58R	78.3 ab	0.327 b	29.80 b	21.08 ab
C	94Y23	70.0 abc	0.372 a	32.52 a	19.62 c
D	93M90	64.8 bc	0.342 b	33.43 a	19.48 c
E	P31T11R	61.4 c	0.344 b	31.41 ab	21.98 a
F	P34T43R2	57.5 c	0.342 b	32.54 a	19.58 c

*Means followed by the same letter did not differ by the Tukey test at 5% significance.

†Concentration of the seed components on a wet basis (13% moisture).

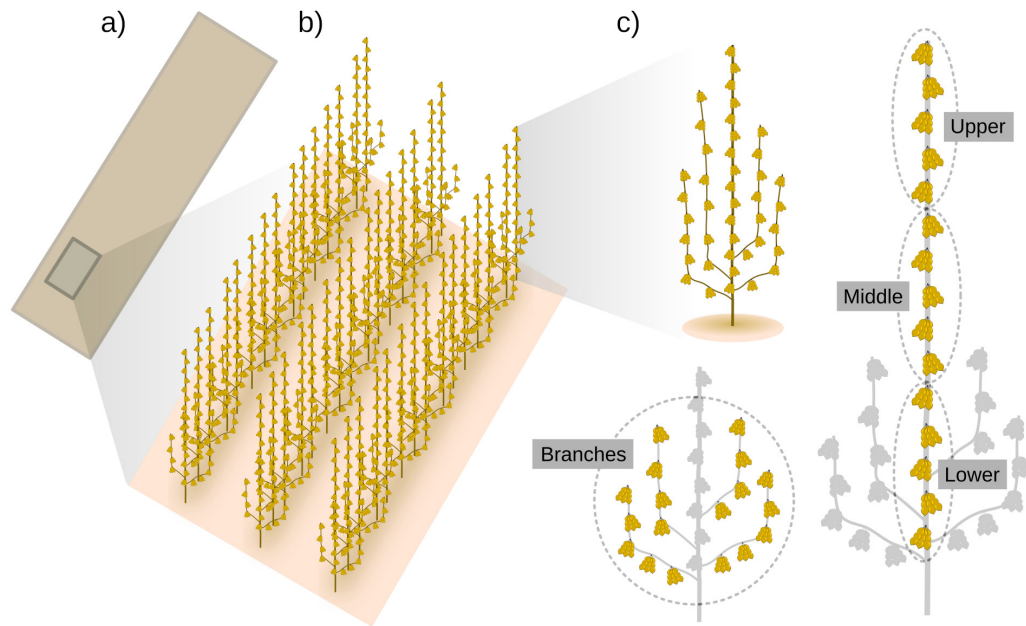


Figure 1. Experimental plots (a) with the harvested area for seed yield and nutritional quality measurements (b). All the plants from the three rows were divided between upper, middle, and lower sections of the main stem, apart from the branches (collected all together) (c).

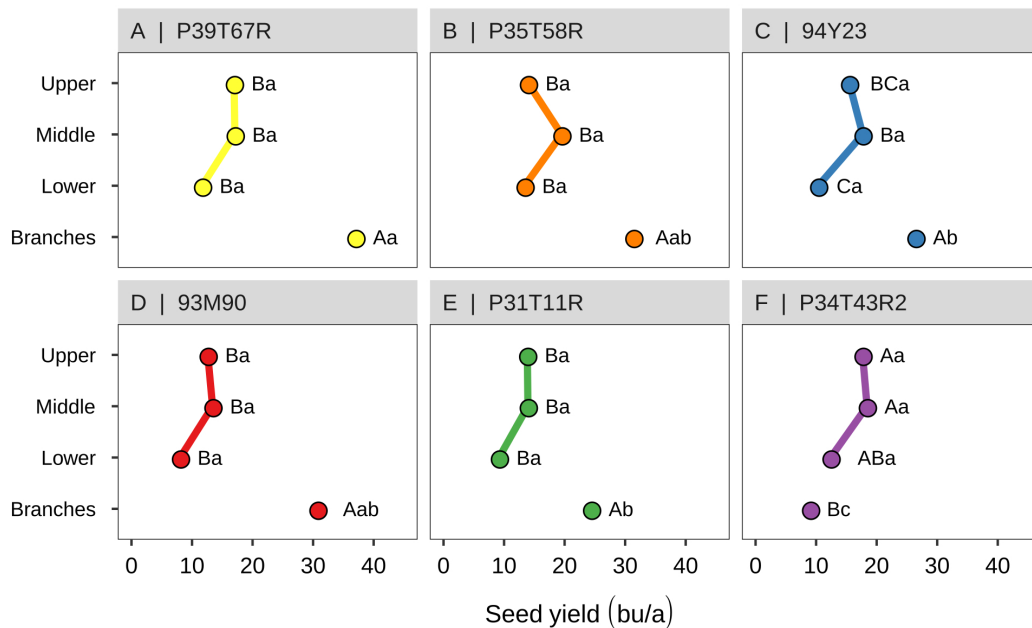


Figure 2. Vertical canopy profile for soybean seed yield (bu/a) for different genotypes. Since the interaction between factors was significant, the Tukey test is comparing genotypes in the same plant portion (lowercase letters) and the portions for each genotype (uppercase letters).

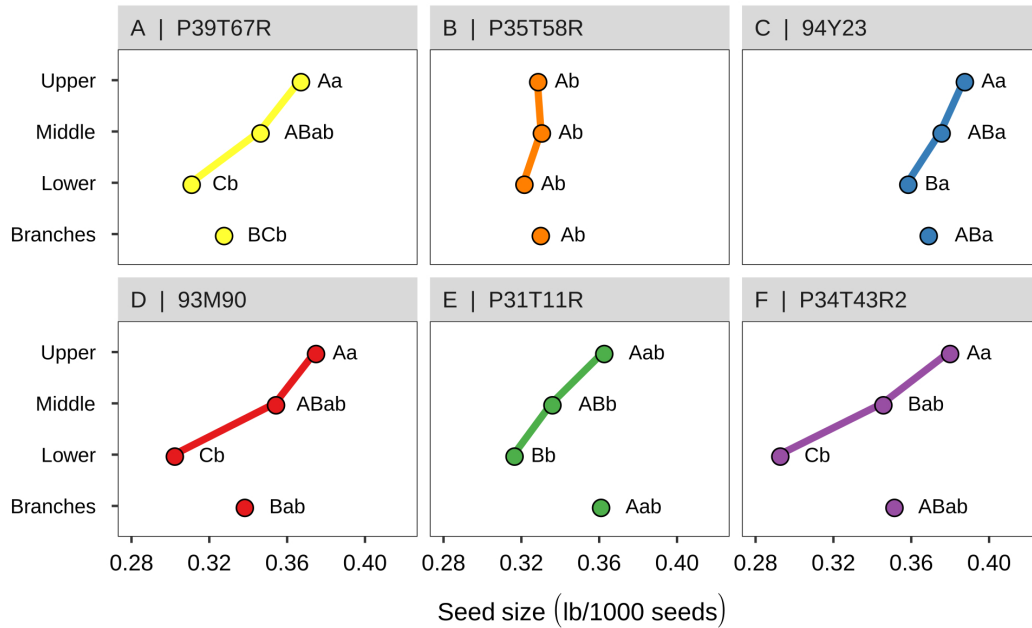


Figure 3. Vertical canopy profile for seed size (lb/1000 seeds) for different soybean genotypes. Since the interaction between factors was significant, the Tukey test is comparing genotypes in the same plant portion (lowercase letters) and the portions for each genotype (uppercase letters).

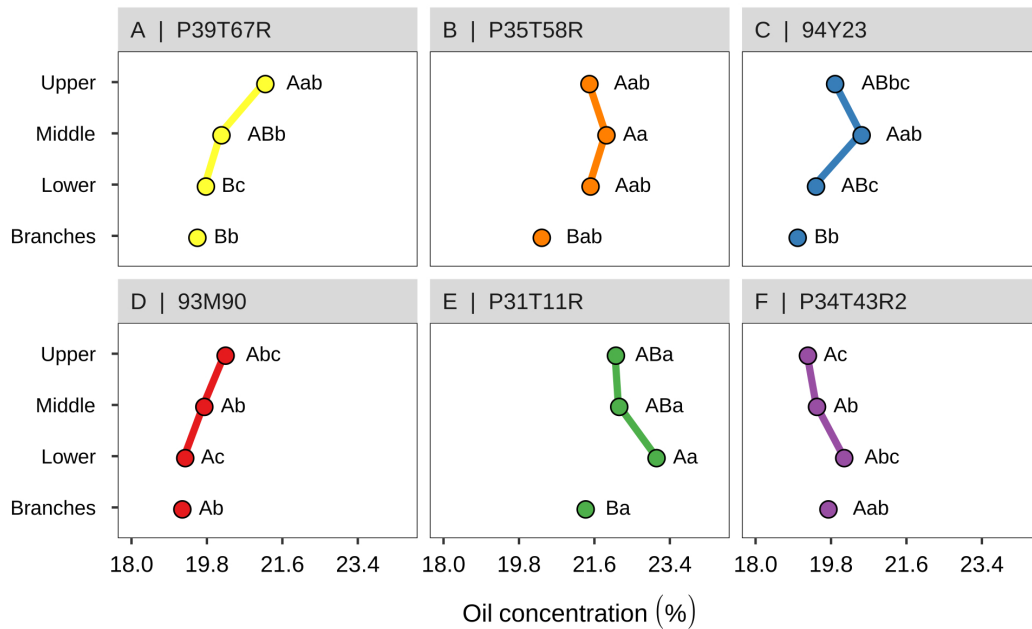


Figure 4. Vertical canopy profile for oil concentration (%) on a 13% moisture basis for different genotypes. Since the interaction was significant, the Tukey test is comparing genotypes in the same plant portion (lowercase letters) and the portions for each genotype (uppercase letters).

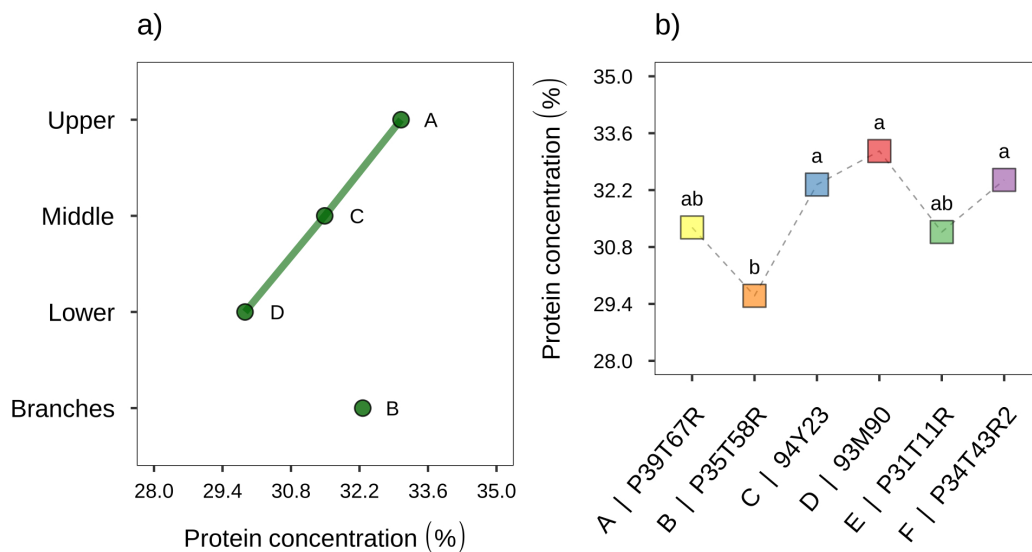


Figure 5. Vertical canopy profile for protein concentration (%) on a 13% moisture basis (a), and genotype comparison (b). Both single factors were significant in the analysis of variance (ANOVA). The letters represent the means comparison by the Tukey test for each factor, at 5% significance.